# LAGRANGIAN OBSERVATIONS OF NUTRIENTS AND PHYTOPLANKTON IN THE CALIFORNIA CURRENT

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## LONG-TERM GOALS

My overall research goal is to understand the coupling of physical processes with spatial and temporal variability in the distribution of phytoplankton biomass and productivity.

## OBJECTIVES

The objective of this research is to understand the relationship of physical processes and the temporal and spatial structure of the phytoplankton community in the eddies and filaments observed off California.

## APPROACH

Twenty-four near-surface drifters equipped with bio-optical sensors were deployed in the California Current as part of the Eastern Boundary Current Accelerated Research Initiative. Deployment patterns consisted of drifter clusters to estimate Lagrangian decorrelation scales in an eddy. The second deployment pattern consisted of repeated cross-shore lines to observe large-scale seasonal patterns.

## WORK COMPLETED

All of the drifters relayed their data back to shore via a satellite link provided by Service ARGOS. The lifetime of the drifters increased from 90 days in the early deployments to nearly one year in the later deployments. The bio-optical data were calibrated through comparisons with limited contemporaneous ship observations. The figure below shows all of the drifter tracks.

We have refined a series of quality control tests for the bio-optical data. Tests were based on local sun angle, degree of bio-fouling (using the ratio of 683 nm to 555 nm

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radiance), and the number of samples averaged per transmitted data point. Drifter position information was also evaluated. We have implemented a system that automatically receives the ARGOS data files, performs the quality checks, and loads the data into a relational data base.

The data base now includes all of the drifter data as well as satellite imagery of sea surface temperature collected and processed by Dr. Ted Strub (OSU). We have built Web-based tools for extracting both data sets and producing drifter track overlays. We also have tools for comparing the satellite observations with the drifters.

We calculated Lagrangian statistics from these drifters. These statistics are used to describe the circulation and bio-optical fields in a moving frame of reference, rather than from a fixed point of reference in more traditional, Eulerian statistics. A paper has been submitted to a special issue of *Deep-Sea Research* on the California Current System.

## RESULTS

Several drifters were trapped by mesoscale eddies, and the cross-correlation functions were calculated for both SST and chlorophyll. In general, changes in chlorophyll lagged changes in SST by one to two days. This was observed for both cyclonic and anticyclonic eddies and supports the hypothesis that the phytoplankton response to changes in the physical environment (and presumably the light/nutrient regime) may be governed by a "shift-up response."

Decorrelation time scales were calculated based on the first zero-crossing of the autocorrelation function, and the biological scales were compared with the physical scales. Time scales for all variables increased as the drifters moved from nearshore to offshore. Nearshore (defined as the region within 200 km of the coast) time scales were two days for both sea surface temperature (SST) and chlorophyll. In the region between 200 and 400 km offshore, the decorrelation scales were six days for SST and four days for chlorophyll. In the region more than 400 km offshore, the SST decorrelation scale was seven days and decreased to 2.5 days for chlorophyll. This pattern of decorrelation scales suggests that the processes regulating the distribution of temperature and chlorophyll are similar in the nearshore region and significantly different offshore. Similar calculations were made for fluorescence/chlorophyll, and the corresponding time scale increased steadily from less than one day nearshore to two days offshore. The rapid adjustments of fluorescence nearshore, relative to changes in pigment concentration, supports the notion that phytoplankton have adopted different strategies for growth in the nearshore versus the offshore region.

Our results suggest that even in an eastern boundary current environment characterized by highly packaged pigments, there are strong differences in ecological strategies along a cross-shore gradient. Although SST and chlorophyll time scales diverge as one moves offshore, one cannot unambiguously assign this divergence to a shift from physical to biological control. Moreover, the SST and drifter speed time scales also diverge. Thus we can only say that the nature of the physical variability has shifted as one moves offshore, and that SST may not necessarily be a particularly accurate indicator of the physical environment offshore. However, consideration of the time scales of fluorescence/chlorophyll suggests that the biological community and the nature of its response to environmental changes as one moves offshore. Thus earlier results that phytoplankton behaved merely as a passive scalar in this region are apparently not applicable to the entire domain. We suspect that in the nearshore domain that indeed phytoplankton (as represented by chlorophyll) and SST are closely linked and respond to similar physical forcing. However, in the transition and the offshore domains, SST is controlled by different physical processes than chlorophyll, and the phytoplankton community shifts from one characterized by non-equilibrium processes to one that is characterized by equilibrium processes.

Chlorophyll fluorescence varies on a wide range of time scales and is sensitive to changes in nutrient stress and species composition. Although this change in the quantum yield of fluorescence greatly complicates the use of fluorescence to estimate phytoplankton biomass, this variability may be used to bridge the gap between the small scales associated with physiological adaptations and the longer scales associated with ecosystem function. In regions of strong vertical motion (such as in areas of active upwelling in the nearshore region), we expect that fluorescence per unit chlorophyll will change rapidly. Our results suggest that there may be different strategies of photoadaptation as phytoplankton communities shift from non-equilibrium to equilibrium. In other words, phytoplankton may always be "tracking" an optimal photosynthetic efficiency, but the closeness of this tracking may vary significantly. This supports the conclusion of other researchers that more effort must be placed on understanding the linkages between phytoplankton physiology and environmental variability.

## IMPACT

Near-surface drifters represent a new tool in sampling the upper ocean. Although they are well-established in physical oceanography, their use is still relatively new in biological oceanography. As phytoplankton are largely at the mercy of upper ocean circulation, these near-surface drifters sample the ocean in a manner similar to plankton. Statistics from drifters can be used to study patch dynamics and the associated time and length scales in relation to physical forcing.

Although bio-optical drifters present their own set of challenges in terms of data processing and analysis, they can provide a more systematic approach for the study of time scales of biological processes in the upper ocean. In the California Current, they reveal that physical forcing may be the ultimate cause that drives variability in the phytoplankton community, but the ecological strategies adopted by the community can significantly modify its impact. Moreover, we cannot neglect the physiological processes in the various species that are at the heart of the community response. Thus future of studies of environmental variability must continue to elucidate both bulk measures of phytoplankton (such as chlorophyll) as well as more species-specific measures.

## TRANSITIONS

Bio-optical drifters similar to those deployed in the California Current are now being deployed in the Polar Front in the Southern Ocean. These drifters also have a Global Positioning System (GPS) transmitter to obtain better position information than is available from standard ARGOS data. Dr. Peter Niiler (SIO) has been funded by NASA to equip operational surface drifters with similar bio-optical instrumentation.

## RELATED PROJECTS

NASA funding has been used to develop and maintain the on-line data base of drifter and satellite imagery. This funding also supported the analysis of the fluorescence data from the drifters. NSF is funding the deployment of bio-optical drifters in the Antarctic Polar Frontal Zone as part of JGOFS.